

NAVAL POSTGRADUATE SCHOOL

Monterey, California



THESIS

**THE ANALYTIC HIERARCHY PROCESS AS A
FRAMEWORK FOR SOURCING DECISIONS:
MANAGEMENT, OPERATIONS, AND MAINTENANCE OF
A PBX**

by

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June 2000

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SOURCING DECISIONS: MANAGEMENT, OPERATIONS, AND
MAINTENANCE OF A PBX**

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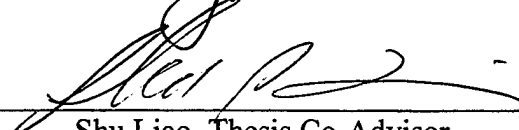
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I. INTRODUCTION

A. BACKGROUND

The only constant in today's Department of Defense (DOD) budgeting process is that each agency is being asked to streamline its operation by pursuing as many cost cutting measures as possible. (Desbrow, 1998)

The Naval Postgraduate School, like other Navy activities is feeling this added pressure in a variety of ways. This thesis will address a decision that NPS has made and the subsequent decisions that are required because of it. NPS has decided to purchase a new telephone switch and now must determine the correct sourcing of its management, operations, and maintenance. This thesis will focus on the decision process of determining whether NPS should manage, operate and maintain the switch with in house resources or contract the functions to an outside vendor. In this case, NPS is looking to find the most efficient method to manage, operate, and maintain its new system. To best understand the options available to NPS, a thorough investigation of other similar telephone system's management, operation and maintenance setups is required. This will then will provide a good frame of reference for this decision for NPS.

In 1996, the National Performance Review recommended outsourcing non-core functions as a means of reducing overall costs of operations and improving business processes across DoD. One way to resolve the issues of constricting budgets and streamlining operations is to consider economies of scale which can be arrived at through outsourcing.

Outsourcing is the transfer of a function, traditionally performed by Government personnel, to the private sector. The government retains responsibility and control of the function, i.e., the service to be rendered, how will it be competed, who will perform the service, and monitoring of the service. Public funds continue to pay for the function by contract with a private enterprise. (Desbrow, 1998)

The philosophy of outsourcing is built on the premise that competition will drive lower or competitive prices. When alternatives exist, customers will choose service providers who will respond to their needs in a timely and efficient manner. This efficient market theory suggests that the competition will drive providers to improve quality, increase efficiency, reduce costs, and better respond to the needs of the customer. The theory further holds that even if government continues to provide the service, the pressure to compete with the civilian sector will insure that government streamlines its own operations.

Another major driving force behind outsourcing is that it should allow the government to focus more on its core competencies and by allowing other organizations to perform its non-core activities. With so many services available in the civilian communities surrounding most installations, it can be argued that there are sufficient service providers to take care of the installation's identified non-core activities. Ultimately if the non-core services can be provided better and cheaper by the private sector, they should be contracted out. By outsourcing non-core activities, organization should expect the improved service, better quality, faster response to new opportunities, and implementation of new technologies and more efficient business practices that would be realized by an organization completely focused on those activities.

An alternative method of gaining from the surrounding community is through Public/Private Ventures (P/PVs).

[A] Public/Private Venture is a business partnership/agreement between the Federal Government and a private company/s, local government, or state government involving the exchange of U.S. Government properties (real estate) and/ or services for moneys and/or services (Desbrow, 1998).

This alternative gives the government the ability to take advantage of the resources of the surrounding community while at the same time retains some government expertise and control in the function. Such a partnership can alleviate the need to cut as many government employees while capitalizing on some of the efficiencies that a complete outsourcing might deliver. This infusion or collaboration of outside expertise and ideas with in-house resources can allow an organization to gain both a sense of ownership of the system and maintain dedication through the government employees. It also acts as a portal to innovation and new ideas into the government from the private sector partner.

B. OBJECTIVE

This thesis will describe the considerations and overall themes that apply to any organization involved in sourcing a telephone switching system. The objective of this thesis is to provide information about the management, operations, and maintenance schemes used by other organizations that operate similar telephone switches as the one that NPS will be operating. This information provides the decision-maker with an understanding of the current practices and lessons learned from other organizations. This thesis also gives the decision-maker a framework that may be used to help make a decision for management, operation, and maintenance of the new telephone switch

system. The framework will provide criteria and alternatives and help rank priorities for the sourcing decision based on the parameters of the telephone switch system.

Finally, the thesis will use a structured framework to analyze the data gathered from other organizations and provide the author's conclusions and recommendations based on his observation of the compiled data. These insights will provide the decision-maker at NPS a concise look and evaluation into possible management, operations and maintenance schemes.

C. RESEARCH QUESTIONS

1. Primary

- a) What are the critical considerations to making a good sourcing decision for Private Branch Exchange management, operations, and maintenance?
- b) Is the Analytic Hierarchy Process (AHP) a reasonable framework to use for telecommunications sourcing decisions?

2. Secondary

- a) What are the inherent risks associated with choosing one method of management and operation over another?

D. SCOPE OF THESIS

This thesis will provide: (a) an understanding of telephone switching systems; (b) a framework for considering the needs and concerns when making the management/

operations source decision; (c) a summary and matrix of the data and concerns gathered from each organization; and, (d) conclusions and recommendations for management and operation of the telephone switching system.

E. ORGANIZATION

Chapter II provides a description of the telephone switching system along with an explanation of the associated functions and terms needed to understand the different management and operational duties. This information is crucial for understanding the data gathered from the source organizations and the conclusions and recommendations made by the author.

Chapter III describes the AHP framework as applied to the data for evaluating the decision matrices. This methodology is the link in the chain between the raw source data and the final decision at NPS. Using this methodology a coherent understanding of the various management and operations schemes and how they can be applied to NPS can be realized.

Chapter IV compares data from the different source organizations. This chapter then evaluates the data and structures it into hierarchies. From these hierarchies considerations and concerns of the different source organizations are evaluated along with current trends in the telecommunications arena to provide the decision-maker the necessary critical considerations for the sourcing decision.

Chapter IV takes the critical considerations and applies it to the decision framework described in Chapter III. From the decision framework, in Chapter V, the author is able to make some general conclusions and specific recommendations to the

decision-maker for his/her management, operations, and maintenance sourcing choice. The information from this chapter should give the NPS decision-maker a good base of knowledge and understanding from which to draw.

F. BENEFITS OF THESIS

This thesis provides the decision-maker at NPS a framework, along with background and information necessary to make an informed decision for sourcing of management, operations, and maintenance of the new telephone system. This includes an understanding of the practices of similar organizations and a method by which to evaluate the different management and operations/maintenance schemes and apply them to the NPS decision. All of this information will ultimately give the decision-maker the ability to make a fully informed decision on the best and most cost-effective sourcing option to meet the needs of the NPS telephone switching system.

II. TELEPHONE SWITCHING AND NPS SYSTEM SETUP

A. BACKGROUND

In order to make recommendations about the sourcing decision for the telephone system at NPS, it is important to understand some basic information about telecommunications, NPS, and its telephone system. This chapter provides that information. It is also important to understand the relationships between the Telephone Company (Pacific Bell, MCI, etc...) and a telephone switching system or PBX. It was an understanding of these fundamental concepts and relationships that allowed the author to generate a data collection methodology and the basic framework for this thesis.

B. THE TELECOMMUNICATIONS RELATIONSHIP

1. What is a PBX

A Private Branch Exchange (PBX) is a phone call routing device better known as a switch. The term switching refers to the completion of the connection between two people for voice communication. One way to conceptualize how a PBX functions is to try to recall the picture of switchboard operators who sat in front of large boards full of holes for phone jacks with each hole connected to a phone. When a call was placed to another party, it was really a request to the operator to be connected to that other party. The operator would then pull out another jack cord and connect the caller to the desired extension. While this is an over simplification, the equivalent of these manual operations are accomplished automatically today through circuitry within the PBX and by

the computers controlling the PBX. Today's systems are extremely advanced and can support and control up to hundreds of thousands of telephone lines. The switching process is further complicated at NPS, because the switch must support not only commercial phone lines, but also handle, the Defense Switch Network or DSN, the military specific world-wide calling network that requires the switch to differentiate between a commercial call and a call between defense organizations on DSN.

The private branch exchange provides the physical connection between the outside line used by the caller and the employee's phone on his or her desk. It is "private" because it is owned by the business or organization and is located on their premises, usually in an air-conditioned closet. It is a "branch exchange" because it makes connections inside the organization in the same way that a normal telephone company exchange such as Pacific Bell connects all of the phone numbers it services in a city or community. The concept of a branched exchange should be familiar to anyone who has used an office extension at a desk or terminal. The larger scale PBX's typically provide additional phone services including internal calling, automatic call distribution (ACD), auto attendant, and voice-mail. These features are usually supported by an integrated computer which is referred to as CTI or Computer-Telephony Integration. The PBX is the heart of the call processing activity and is central to any large organization's ability to use voice communications. (Computer Telephony.Com, 2000)

2. Telecommunications Set-Up

Now that there is a general understanding of the PBX, it is possible to further expand upon the relationship between the PBX and the telephone company or service

provider. The telephone service provider, like Pacific Bell, controls the telephone service to a particular area. Whether it is a business, organization, city, county, or state the general idea is the same. Each area serviced by the service provider is designated by a three-digit area code and then within that area code there are 3 digit prefixes specific to certain regions. For example the area code for the Monterey Peninsula, CA is 831 and the local prefixes vary throughout the 831 area code including 372-XXXX in Monterey and 457-XXXX in Santa Cruz. Some or all of the numbers within the three-digit prefixes can be reserved for large organizations or businesses that want to have the same prefix for all of their numbers. This allows two things; easy expansion for the organization within its block of numbers and the ability to use only the last four digits of a telephone number to make inter-organizational calls. These blocks of numbers are purchased from the service provider and are called DID's or Direct In Dials and DOD's or Direct Out Dials. NPS has the DID/DOD block of 831-656-XXXX.

Once a block of numbers is set aside for an organization there are two options. The organization can use the telephone company's switching services commonly known as "CENTREX" or they can provide their own switching services (i.e., PBX). By choosing to run a PBX the organization now acts like a mini-telephone company in that they have the ability to assign numbers to different offices, route calls and provide voice-mail services just like those that subscribe to a CENTREX plan. From the earlier discussion, recall that the advanced computer backed switches allow for all such services to be handled via on screen commands. Furthermore, the organization with its purchased DID/DOD trunk group is tapped into the local service provider via a fiber optic trunk or grouping of many phone lines running to the service provider's local area switch.

Typically, there are 10-20 lines per trunk and a commercial PBX user purchases trunking on a ratio of 7 to 1 while the government typically uses a 10 to 1 ratio. What this means is that for every 7 or 10 phone numbers/stations, more commonly referred to as phone lines, there is only one line leaving the PBX to the local service provider. So for a 3400 station government system there will typically be approximately 340 lines of trunking space purchased from the local service provider. This setup cuts down on cost due to fractionalized purchasing, that is, buying a phone line for each station, because the likelihood of every station needing a dial tone at the same time is very small and extremely unlikely. (Doug Picard, 2000) When a person in an office picks up the telephone and they hear a dial tone the PBX has searched the available lines, in this case the 340 of them, to find an open one for that person on this particular telephone call.

Once an organization has elected to run its own switch it assumes responsibility for management, operation, and maintenance of the switch. For the purpose of this thesis each of these terms will be defined as follows:

a. System Management

The system management refers to the overall monitoring of the operations and maintenance of the switch. Specifically management involves responsibility for ensuring that the switching system remains operational and that all billing is accurate and timely, the contracts are set up, and personnel relations are handled properly. In addition, management includes responsibility for keeping abreast of new developments in telecommunications and updating the software, personnel, and system components accordingly. These updates include sending personnel to training on new components and software and keeping a constant watch over potential cost saving system

changes or developments. Good system management is integral to long term viability of the PBX and if conducted properly the system should remain current, and capable of meeting the organization's demands for many years.

b. System Operation

Switch system operation refers to the daily processes associated with the switch and its component functions. The processes and functions range from conducting Moves, Adds, and Changes (MAC's), to processing voice mailbox requests to dealing with billing issues. MAC's are the process of making new extension assignments, changing existing assignments, or adjusting current assignment setups. With the new switch system at NPS, MAC's are carried out with computer software via the drag and drop function. The billing function includes receiving and interpreting charges from the local service provider, interpreting charges from long distance providers, and relaying those charges to the appropriate billing source. System operation also includes review of system usage for volume trend analysis, proper trunk size, and for improper or excessive usage. By analyzing call volume, the system operators can help to minimize trunk purchases for low volume periods thus lowering costs and ensure that there is enough trunking capability for high volume periods. In addition, by tracking excessive usage, the operator helps to cut down on fraud, waste, and abuse. The operation of the system is key to maintaining congruent system performance.

c. System Maintenance

The maintenance of the PBX is very limited due to its high reliability. The system is designed to be up and running without problems 99.999 percent of the time. If the system should ever go down, maintenance should consist of replacing one of the

cards within the switch, rewiring a component within the switch, or some other physical repair of the switch system. The maintenance could also deal with reprogramming of the factory-set, internal software within the switch that controls the call processing functions of the PBX.

C. NPS PBX SETUP

The Naval Postgraduate School operates both like a university campus and a military base. It contains telephone service for faculty, staff, military support activities (i.e., Morale Welfare and Recreation, housing, personnel support, etc.), Video Teleconferencing (VTC), and limited authorized student use. In terms of size the NPS planned system will support 1,654 digital and 208 analog stations (lines) with possible expansion to 3,400 digital and 600 analog stations (Booz-Allen & Hamilton, 2000). The consulting group of Booz-Allen & Hamilton Inc is developing the design specifications and layout for the new switching system. Their report, issued to the Chief Information Office (CIO) of NPS, outlines in detail the switching system specifications and layout.

From the System Design document prepared by Booz-Allen & Hamilton Inc., the new PBX will be a digital switching system that conforms to North American industry standards. The PBX network will be modular and able to expand or be made smaller depending on NPS growth. The PBX will have capabilities consisting of integrated voice, data, and image communications. The new system will permit a seamless transition of telephone and integrated voice services at NPS. The new design will abandon current exterior telephone cabling (i.e., building to building), but will use the current interior cabling infrastructure and will rely upon the vast amount of existing

fiber optic backbone, which supports the data network, for exterior cabling. The new system will support the features in Figure 2-1 which represent the basic office calling functions. These allow for an office and a caller to have conference calling, transfer calls, and call privacy.

BASIC TELEPHONE SWITCH SYSTEM FEATURES

Visual identification of voice mail.
Do Not Disturb (DND) capability.
Speaker phone capability.
Support for on-hook dialing.
Conference capability.
Intercom support.
Cross-the-network ANI and DNIS support

Figure 2-1 (Booz-Allen & Hamilton Inc., 2000)

The voice mail system will provide network wide access and transparent conversion from the old and very limited CENTREX based voice-mail system. The system specifics are summed up in Figure 2-2. In addition to standard voice-mail capabilities the NPS system will have flexible auto attendant functionality and the ability to provide announcements or voice bulletins to both callers inside the NPS DID block and to callers outside NPS calling in to the NPS system. The system will also have network database access through CTI, broadcast, out-calling, and multilevel security capabilities. These capabilities are the backbone of the computer telephony integration and will allow the NPS user the ability to check, manage, and organize their voice and fax messages through their email in-boxes. All of these capabilities will be compatible with the existing Navy IT-21 compliant Microsoft Exchange e-mail system.

Basic Voicemail System Features

Feature transparent operation over the Naval Postgraduate School network (Network Message Service)
Multi-level automated attendant
Voice bulletin board or Announcement capability
Dual language prompting at select locations
Disk back-up and disk shadowing
Single terminal access-one terminal for administration of E-mail and PBX
Off network access to mailbox and messages
Ability to alert pagers and cell phones to urgent messages
Message addressing and broadcast message capability
Multi-level security capabilities

Figure 2-2 (Booz-Allen & Hamilton Inc., 2000)

This chapter provides the background necessary to understand the remainder of this thesis. Specifically, it outlines the general information on telecommunications, PBX switching, and the Naval Postgraduate School setup. This understanding will ultimately allow for a richer understanding of the tradeoffs and alternatives presented later in this thesis.

III. THE ANALYTIC HIERARCHY PROCESS

A. INTRODUCTION

This thesis will use the framework and methodology of Thomas L. Saaty's, Analytic Hierarchy Process (AHP), to help organize and analyze the data and information gained from several other organizations which operate PBX's. This structure could then be used by a decision-maker to guide his or her thinking. In problem solving there are various routes which can be taken to help arrive at a decision; two of the most common are the systems approach and the deductive approach. The systems approach looks at the problem as a whole or total system whereas the deductive approach systematically focuses on individual parts of the whole problem to come to a solution. The reason the AHP was chosen to present this problem was due to its ability to "[combine the] two approaches into one integrated, logical framework." (Saaty, 1990, p. 13).

1. Coping with Complexity

Human beings often look at complicated problems and fret over the necessary effort needed to solve the problem. Humans almost always over-think and complicate problems, by assuming that the method for solution involves complicated thinking where in fact simple organized thought could just as easily present a solution (Saaty, 1990).

Other times, humans are confused as to which one of the many objectives before them is the best choice. Saaty describes this dilemma:

Leaders may be confused by the diverse information provided by their assistants; they may need help in identifying differences of opinion and seeing positions where compromise can be reached. They may know which important issues must be researched in depth to obtain better

information and how sensitive the outcome is to slight or drastic changes in opinion and judgements. Increasingly we need to articulate and map out the issues to see whether what we think and what we feel lead us to the same kind of answers (Saaty, 1990, p. 4)

So to cope with the complexity of problems and the self imposed complexity added by the human mind, there needs to be a simple organization of thought and a way to achieve congruence of ideas.

2. Organizing Knowledge for Decisions

The two methods of organizing a problem, deductive and systems approaches, both have their strengths and weaknesses. Since the AHP was designed to encompass the strengths of both of these methods, it is important to have a general understanding of each method. The deductive approach involves looking at the problem as a network. Then from the network layout, one can derive an understanding of the complete problem by looking at the interconnection of the network's functioning parts. This process is effective but tends to neglect the feedback "among the parts and between the parts and the environment that affect the whole system" (Saaty, 1990, p. 5). The systems approach takes a more general approach to organizing the problem by looking at the entire problem or system and its relationship with its environment. This approach does not focus as heavily on the parts of the problem, thus it may provide only one dimension of understanding.

By combining the best of both of these approaches, a better approach to problem solving can be derived. "The AHP enables us to structure a system and its environment into mutually interacting parts and then to synthesize them by measuring and ranking the impact of these parts on the entire system" (Saaty, 1990, p. 6). This method allows the

decision-maker to encompass the entire scope of the problem and then present it in an organized fashion. This model is ideal for the decision-maker dealing with complex problems with many alternatives.

B. BASIC PRINCIPLES

There are basic principles fundamental to the AHP. This section briefly discusses each of the principles. They are: (1) Constructing Hierarchies; (2) Establishing Priorities; and (3) Logical Consistency (Saaty, 1990, p. 17).

1. Constructing Hierarchies

A human, as a decision-maker, has been given the ability to understand things and ideas in a logical and consistent manner which allows him or her to communicate effectively with others and explain what they see. The mind begins to organize and place the different parts of the problem into manageable sections or parts which are then grouped and aligned in some sort of order according to the individual decision-maker's perspective. This organization is what Saaty calls a hierarchical structure with "the number of parts usually ranging between five and nine" (Saaty, 1990, p.17). Through breaking-down a problem into these parts, a large amount of information can be assimilated into a structure that allows for a good view of the complete scope needed for problem solution. (Saaty, 1990)

2. Establishing Priorities

The decision-maker's mind naturally compares pairs of similar things against distinct criteria in order to derive a preference of one over the other. By collecting these preferences for many paired comparisons and then organizing them with the AHP, the decision-maker can then gain an understanding of the whole system. The pairwise comparison ultimately gives the user the ability to rank and compare parts from one order of the hierarchy to another. (Saaty, 1990)

3. Logical Consistency

In order to best comprehend the relationships between and among objects, humans must arrange them in a manner which is coherent and leads to consistency across different comparisons. "Consistency means two things; the first is that similar ideas or objects are grouped according to homogeneity and relevance, the second meaning is that the intensities of relations among ideas or objects based on a particular criterion justify each other in some logical way" (Saaty, 1990, p.18). The AHP integrates both the quantitative and qualitative ways in which the human mind thinks. First, it allows the decision-maker to define the problem and its hierarchy qualitatively and then to synthesize the problem by assigning some measure that allows quantitative insight into concise preferences. In order to make complex decisions, it is important to consider both of these qualities, because the most sound method of choosing between qualitatively assigned categories is through quantitative priority determination. This dual property process is a practical method of generating measurement scales. (Saaty, 1990)

C. THE BASICS OF THE ANALYTIC HIERARCHY PROCESS

“The analytical hierarchy process is a flexible model that allows individuals or groups to shape ideas and define problems by making their own assumptions and deriving the desired solution from them” (Saaty, 1990, p.22). The power of the AHP comes in its ability to accommodate human nature by keeping decision making within a scope that does not work counter to the decision-maker’s better judgement. The AHP blends the decision-maker’s judgements and values in a logical way and lets his or her experience and knowledge of the problem construct the hierarchy that will be used for its solution. By accepting the methods of the AHP the decision-maker can connect the information from one part of the hierarchy to those of another in order to gain and assess the interactions of the whole system. (Saaty, 1990)

When using the AHP to deal with a complex problem, the processes of developing and refining the model must be repeated through several iterations in order to derive an accurate solution. “The AHP is flexible enough to allow revision—decision-makers can both expand the elements of a problem hierarchy and change their judgements. It also permits them to investigate the sensitivity of the outcome to whatever kinds of change may be anticipated” (Saaty, 1990, p. 22). As with any process, the more iterations that are run the more refined and concise the decision and final outcome will be. The ability of the AHP to allow revision and adjustments is a reason that it is a good framework for a constantly changing environment like telecommunications. The process also may be useful for analyzing the impact of planning and policy decisions and for resolving decision conflicts. Figure 3-1 describes the advantages of AHP over other decision frameworks.

The AHP allows the decision maker the ability “to consider a problem as a whole and to study the simultaneous interaction of its components within a hierarchy” (Saaty, 1990, p. 24). This provides the decision-maker with a much richer understanding of the problem. From the priorities generated by looking at the problem with the AHP, the decision-maker has the ability to consider all aspects of the problem. This should lead to a better decision.

Ultimately by using the AHP the decision-maker can expect to gain the following as outlined in Saaty:

1. A practical way to deal quantitatively with different kinds of functional relations in a complex network.
2. A powerful tool for integrating forward (projected) and backward (desired) planning in an interactive manner that reflects the judgements of all relevant managerial personnel. The output of this process is explicit rules for allocating resources among current and new strategy offerings-or to satisfy a specific set of corporate objectives-or under alternative environmental scenarios.
3. A new way to:
 - Integrate hard data with subjective judgements about intangible factors.
 - Incorporate judgements of several people and resolve conflicts among them.
 - Perform sensitivity analysis and revision at low cost.
 - Use marginal as well as average priorities to guide allocation.
 - Enhance the capacity of management to make tradeoffs explicitly.
4. A technique complementing other ones (benefit/cost, priority, risk minimization) for selecting projects or activities.
5. A single replacement for a variety of schemes for projecting the future and protecting against risk and uncertainty
6. A vehicle for monitoring and guiding organizational performance toward a dynamic set of goals. (Saaty, 1990, p.25)

AHP: A FLEXIBLE MODEL FOR DECISION MAKING

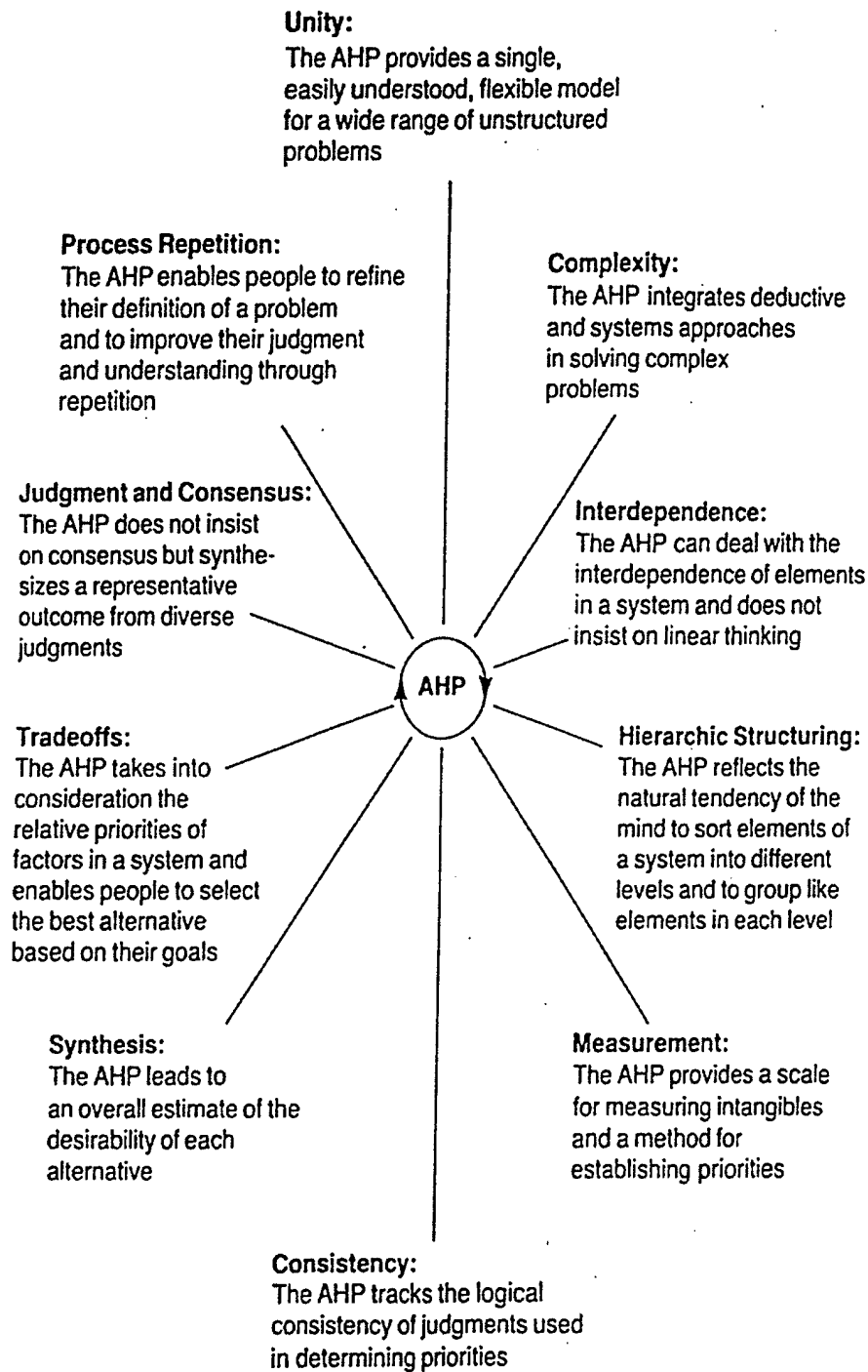


Figure 3-1. Advantages of the Analytic Hierarchy Process.

(Saaty, 1990, p. 23)

D. STRUCTURING HIERARCHIES

The AHP relies on constructing and analyzing hierarchies. Constructing a hierarchy involves breaking the problem into its component parts so that it can be ranked, organized, and structured into a manageable form. This hierarchical structure is the method by which the human mind best dissects and understands a problem, thus a clear understanding of how to classify and construct hierarchies is needed.

1. Classifying Hierarchies

When classifying hierarchies one must first understand that there are two different types: structured and functional. Within the structural hierarchy a complex system is broken down into its rudimentary parts based on structural properties which are then organized in descending order. For humans, structural hierarchies allow our natural brain functions to easily break down systems into sub categories and thereby enhance one's understanding of the problem.

On the other hand, functional hierarchies use the "essential relationships" (Saaty,1990, p. 28) to break down a complex system into its rudimentary parts. AHP generally uses functional hierarchies. In a functional hierarchy, each set of elements rests at a different level on the hierarchy with the top level called the focus. The focus has only one element. This focus element is broad in coverage and objective. Each subsequent level can have several elements, normally between five and nine. Each level relates to the level above it. For the hierarchy to be set up properly, all elements on the same level must be of the same magnitude and share the same properties. The links among the elements on a level allows for consistent comparisons between levels. In keeping with

the structure of the human mind, the functional hierarchy is flexible and able to make interconnections and comparisons between and among different levels within the model.

2. Constructing the Hierarchy

The construction of the hierarchy is the key to success in the AHP, but at the same time there are no set rules for constructing one. This no rules approach means the AHP can be molded to fit whatever problem a decision-maker is facing. The type of hierarchical structure is completely dependent on the type of decision and on the decision-maker. For this thesis, we will consider the structure that deals with choosing among alternatives as described by Saaty.

If it is a matter of choosing among alternatives, we could start from the bottom level by listing the alternatives. The next level would consist of the criteria for judging the alternatives and the top level would be a single element, the focus or overall purpose, in terms of which the criteria can be compared according to the importance of their contribution. (Saaty, 1990, p. 30)

Comparisons would then be carried out with the intent of determining each lower level's contribution to the overall goal of the hierarchy. It must be noted that even when the elements have been placed on certain levels, the hierarchy can still be changed to accommodate new changes or fields of view.

To best understand how constructing hierarchies can be applied it is instructive to look at a sample problem, for example, the hierarchy that might be used for choosing word processing equipment, Figure 3-2. In this hierarchy, cost and benefit are built as separate structures. Both cost and benefit each represent level one foci with the desired criteria as described by the user listed on level 2 of the structure. The third level in the benefit structure consists of the desired

equipment characteristics. While the fourth level consists of the alternatives to word processing level and are linked to the features they use for comparison to those that are desired. The same type of waterfall is used to breakout the criteria and alternatives for the cost hierarchy.

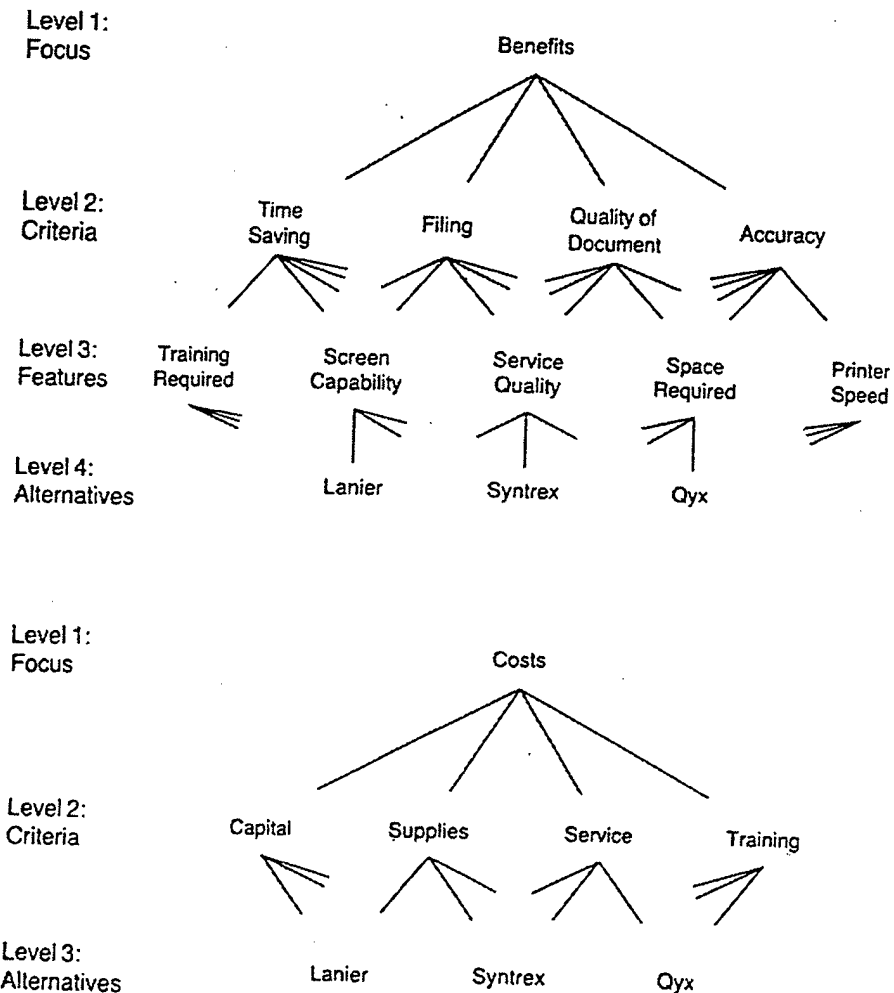


Figure 3-2. Hierarchies for Choosing Word Processing Equipment.
(Saaty, 1990, p. 38)

To help the reader structure a hierarchy, Saaty lays out a list of steps and considerations the reader should follow to develop a suitable hierarchy for their needs:

1. Identify overall goal. What are you trying to accomplish?
2. Identify subgoals of overall goal.
3. Identify criteria that must be satisfied to fulfill subgoals of the overall goal.
4. Identify subcriteria under each criterion. Note that subcriteria may be intervals of numerical values; or intensities such as very good, good, average, and excellent.
5. Identify in descending levels, as needed, actors, actor objectives, and actor policies in this order.
6. Identify alternatives or outcomes.
7. For yes-no decisions include for example doing and not doing the alternative.
8. It is often useful to construct two hierarchies, one for benefits and one for costs to decide on the best alternative, particularly in the case of yes-no decisions. Ratios of benefits to costs, are formed and the alternative with the largest ratio is chosen. Which alternative yields the greatest good. (Saaty, 1990, p. 33)

E. ANALYZING THE HIERARCHY/MAKING THE DECISION

Once the hierarchy is constructed, the decision-maker would then use the hierarchy to make the decision. For simple problems, such as the word processing one described above, the decision-maker might assign a simple yes or no or value judgement (Poor, Good, Fair, or Excellent) to indicate how each one of the alternatives meets the Level two and three criteria and future requirements. It would then be relatively simple to see which alternative should be selected. For more complex problems, the decision-maker might assign a number rank or priority to each of the possible alternatives within the hierarchy. From this ranking the different alternatives are set into a decision matrix.

From the decision matrix the decision-maker can use Expert Choice software to come to a matrix solution based on the different weights that were applied to each of the different decision alternatives.

For the purpose of this thesis the AHP framework will only be used to construct the hierarchies and layout the different considerations and alternatives. The AHP will effectively construct a clear picture of the alternatives and considerations to be made with regards to the Naval Postgraduate PBX system. Since the author is not in a position to assign weights or to prioritize the different alternatives for NPS, the author will base his conclusions on the inputs from the other data sources and use what the data sources ranked as priorities for their systems.

IV. CONSTRUCTING THE AHP FOR THE NPS DECISION

A. ASSESSMENT OF DATA FROM ORGANIZATIONS

This thesis involves the decision on how NPS should manage, operate, and maintain its new telephone switch. In terms of the AHP, we needed to identify the alternatives and the criteria for other levels of the hierarchy. By looking at other organizations, we learned what was important to them and some of their lessons learned from their experience with telephone switch function sourcing. This chapter describes this process.

1. Data Gathering

To provide a framework for the decision to manage, operate, and maintain the planned NPS telephone switch, an understanding of the NPS switch requirements was necessary. It was also important for choosing data sources that resembled NPS in set up and general structure. To meet these criteria the author looked to organizations that had a campus type environment or organizations that would have many users spread over a relatively large area. The latter criteria would lead the data source to need a telephone switching setup and further would most likely need to operate or have operated a private branch exchange.

Data collection consisted of a semi-structured interview and survey. An initial set of questions was generated based on consultation with several telephone system professionals and research on telecommunications systems. The set of questions was designed to extract details from the data sources that could be used to frame the decision

for NPS. The set of questions can be found in Appendix A. The primary method for gathering responses to the question sheet was through email with follow-up via telephone conversations and fax correspondence. All the data sources were asked to provide both numerical data and commentary about their system set-ups. They were asked to comment on the advantages and disadvantages of system set ups, and on their level of satisfaction with their structure. Recent changes that may have occurred to their PBX systems that may have significantly altered the method in which they conducted their day to day switch operations were also noted.

2. Description of Data Sources

Since some of the organizations were concerned about the propriety of their information, all sources are referred to by masked references. These will fall under the form of Universities A through F, Corporation one, and government agency one. The majority of the data sources were universities due to their close resemblance to the structure and layout of the Naval Postgraduate School. Looking at other universities as data sources, whether larger or smaller, provides the best correlation due to the faculty, student, and administrative structure and relationships. The corporate source provided another aspect to the PBX system structure and allowed for a departure from the university style structure that helps to lend perspective on possible different approaches to PBX system structuring. This might provide some innovation and ideas that the corporate sector may infuse that may differ from a university perspective. The different universities ranged from just slightly larger than NPS to almost ten times the size of NPS.

In any case the methods in which their systems are structured can be linked to NPS because their core PBX systems have similar capabilities to that planned for NPS.

University A operates several switches at its campus, each with a slightly different system structure. The university is a large private university that has both graduate and undergraduate schools linked together under the telephone switching setup. They use approximately 18,000 lines, which are spread over 4 different switch setups. They use GTE Centranet, a 5ESS switch, for roughly 10,000 lines, Pacific Bell Centrex for roughly 600 lines, and a university owned and operated, G3I, PBX handles about 7,400 lines. They currently offer voice mail, call tracking, and other similar services to the NPS PBX. For personnel, they have eight people in operations performing customer interface, trouble call receipt and tracking. There are three people that handle technical support, vendor management and planning. Outside vendors provide station and cable installation and repair. The university staff is not solely dedicated to the PBX system, but also deals with all forms of the network and communication links.

University B operates their own Ericsson switch that supports 5500 lines for 9000 customers. University B is a public university that has both graduate and undergraduate schools linked with its telephone system. Their operations are like a commercial telephone company with all revenues and funds being generated by their customer base. They have operated the switch since 1984 and provide the full range of telephone services to include billing, call tracking, and voice mail. They conduct about 12,000 MAC's per year with 4500 of them associated with entering and departing students every fall and spring. On the personnel side, there are 12 full time equivalents (FTE), five customer service representatives (CSR), two programmer analysts who do billing, one

telephone company analyst to deal with the telephone companies, one voice services analyst that manages the PBX, two contract PBX technicians, one telecommunications manager, and five network technicians on-call for MAC's.

University C provides service for 35,000 phone lines with a Nortel SL-100 switch and 50,000 network addresses that service 20,000 voice mail boxes and 7,000 category five (CATV), network cable drops. This PBX services a large campus of both undergraduate and graduate schools spread over several miles along with several satellite locations. The telephone switching and computer network operation are conducted and arranged under linked staffing. The university conducts 14,000 MAC's per year along with 3,500 trouble calls and approximately 40,000 help desk calls. For personnel, there are five technicians as CSR's, five field technicians that do MAC's and wiring along with maintenance and operations, and four system engineers for planning, provisioning, and advanced trouble shooting.

University D has been running its own Lucent Definity G3R for the past eight months and used to run a Mitel SX200 for the previous past 15 years. The University switch services both undergraduate and graduate schools on a medium size campus. The switch at University D is sized to support 10,000 stations, but is currently operating at 6,000 stations and growing. The PBX is serviced by 375 trunks, 1500 MAC's are performed per year and the system offers all of the features that the NPS switch will be set to offer. The telecommunications staff performs operations and basic maintenance with two full time equivalents and 40 hours per week of part-time assistants. Advanced maintenance and repairs are contracted with the switch vendor.

University E has a 5800 station, 5ESS, switch since 1994 that services undergraduate faculty, staff, students, and support elements. The university is medium in size and is very similar in structure to NPS. The system is roughly 70 percent analog and 30 percent ISDN. They provide 2800 voice mailboxes and conduct trunking or call volume analysis. For personnel, they have two government service employees, one dedicated to voicemail service and the other doing MACs; they also have telephone company technicians that do cabling on call and some MACs.

University F has been running a Lucent G3R, 1491 station, switch since 1997 that services faculty, staff, and students. The university is a small public undergraduate and graduate university that has a student body of approximately 2,000. They contract their switch maintenance with a 24 hours a day/ seven days a week (24/7) through the vendor for all functions of their switch. They have a staff of seven. Two people are telecommunication technicians, two people handle the data side, one person does video with support from the two telecommunications technicians, one person handles the accounting and the other person is responsible for taking service orders, repairs, and acts as a receptionist.

Corporation One has been running a Nortel Meridian 1 Option 81C switch since 1995. They have offices based all over the country, but within California they have 3500 physical lines, but 400 of them are phantom lines. Their voicemail is provided by an Octel 250/350 system. They contract with one source for all functions, but do their own MACs and have a separate contractor that processes the billing.

The government agency updated their switch to a Lucent Definity digital switch that services 4600 stations with expandability to 6000 stations from an older Lucent

digital switch model. They conduct 300 to 500 MAC's per year over a site that covers about 50 square miles consisting of administrative offices and work centers. They contract all maintenance functions through vendor support and conduct their own MAC's. They have five people working in the telecommunications department that handle the management and operations functions. However, the billing is routed through another government agency and then routed back to the agency for prosecution and payment.

B. GENERAL OBSERVATIONS

An analysis of the responses of the different organizations indicated certain trends and common themes among the organizations. The different issues and methods of conducting PBX functions were both implicitly and explicitly addressed within the responses. This section outlines the trends, issues, and methods that form the basis for developing the functional criteria of level two in the hierarchy for the NPS PBX decision presented in section C.

Across the organizations there were several issues with regard to management, operations, and maintenance that received specific attention by the organizations. The organizations revealed considerations that should be taken into account when making sourcing decisions. These areas pertain generally to all three of the major functions of management, operations, and maintenance and will form the level two, functional criteria, of the AHP hierarchy for NPS. However, the organizations had difficulty identifying their costs and from where exactly they were generated which limited the

scope of analysis. The decision-makers at the various organizations generally identified the following areas as cited.

1. Level of Responsiveness

In all sourcing decisions there must be a consideration of the level of response that is acceptable to the organization. This applies to MAC's, customer service interfaces, and maintenance. This aspect is particularly important due to the necessity to maintain a highly reliable method of communication. This also can lead to high or low customer satisfaction in terms of the timeliness of requested service additions or changes like voicemail.

2. Level of Control

The level of control is another aspect that is totally subjective and requires the decision-maker set a threshold. The more the employees are not under the organization's control the less control the manager has over the system and its functions. Level of control also plays a large part in all of the other considerations, because it represents the sum total of all the decisions on responsiveness, quality, and system adaptability ultimately determining the overall level of control.

3. System Updates

The decision-maker must also look at which sourcing options provide the best opportunity for keeping the system up to date as PBX technology evolves. Keeping up to date does not only apply to software, hardware, but also means that the PBX technicians

have up to date training. This consideration is vital to the long-term viability of the system, because as the organization becomes more interconnected and voice and data begin to converge, the PBX must be able to handle advances in VTC and data transmission over telephone lines.

4. Additional Considerations

In addition to these considerations, the expertise level of the personnel working within the system is paramount for successful and precise management, operation, and maintenance of the PBX switch system. The amount of expertise and the cost of maintaining that expertise varies over the different sourcing options. The decision-maker must ultimately decide on what threshold of expertise is required for each function of the switch system and how they are going to maintain that expertise.

Cost factors encompass all of the above considerations and must be weighed on top of the acceptable level of the other criteria. The cost factor is the single most volatile consideration, because it is affected by all of the others. A consensus from the organizations confirmed the thought that obtaining the highest levels of any of the functional criteria could only happen at very high cost. With this said, to manage cost the decision-maker must manage the thresholds that are set along with the sourcing choices that are made. For the decision-maker to best achieve his/her cost objective, he/she must get the greatest value for the dollar and carefully evaluate the sourcing options in both the long run and short-run.

As expected, the organizations handled the actual management, operations, and maintenance of their switch systems by several distinct approaches. The three main ways

were the use of totally in-house employees to conduct all three PBX functions, a mix of both contract and in-house to conduct the functions, and a complete outsourcing of their PBX functions. These three distinctions serve to make up the level three, the alternatives for sourcing, section of the AHP hierarchy for NPS. Of those organizations that chose to either provide support through in-house or a mix of contractor and in-house, all seemed to opt for switch vendor support when it came down to major or serious PBX service break-downs. With major breakdowns an infrequent occurrence, this arrangement is logical because vendors normally have the most expertise with the system when major breakdowns do occur. These three alternatives are quite general and are simply a basis from which to start. The different organizations also broke down the three major sourcing options even further by applying them differently in some cases to each function, management, operations, or maintenance, of the PBX switch. University D, for example, uses a mix of both in-house and contracted support. After installing their new switch the in-house staff received enough training to conduct operations, which included MAC's, voice mail processing, and minor maintenance, but advanced system maintenance was contracted with the vendor. The added dimension of mixing and matching the possible sourcing options is what leads the author to break the decision hierarchy into three individually but linked hierarchy structures.

C. STRUCTURING THE DATA THROUGH THE AHP

For this thesis, there are three linked hierarchy structures that will be laid out in this section. Recall the word processing example used in Chapter III, Figure 3-2, where the decision was broken into two separate but related hierarchies, Benefits and Costs.

This same methodology will be used to design the hierarchy for the NPS decision-maker. The three hierarchical structures will consist of one for management, one for operations, and one for maintenance

1. Level One

The NPS hierarchy structures will have management, operations, and maintenance as the level 1 or focus for each of the three separate but linked hierarchy structures. The final NPS sourcing decision entails making a decision on these three functions together, but to best understand and evaluate the considerations and trade-offs that are associated with one decision over another one must look at each as the focus of its own decision hierarchy. Management, operations, and maintenance became the three foci due to the unique and individual nature of each function. The impact of different considerations on each function varies depending on the consideration so they must each be evaluated as their own decision hierarchy.

2. Level Two

Under the level two, functional criteria of the hierarchy, the general considerations of responsiveness, system updates, control, personnel expertise, and cost factors apply generally to all of the foci. However, within each separate hierarchy the functional criteria encompass tasks and meaning specific to that function. For the management hierarchy as shown in Figure 4-1, responsiveness refers to software repair and updates, billing and customer service which are judged effective by the timeliness of their implementation. Within the realm of the system updates, management must ensure

that they are forward looking and catch updates to billing processes and software. At the same time the control threshold over training and telephone company contracts must be evaluated, because it is most likely determined by who is in charge of the personnel. The personnel must have the proper training to conduct the requisite work and customer service. The cost factors that apply to management must be weighed against all of the other acceptance levels to determine if the cost objective for management can be met.

For operations, Figure 4-2, MAC's, customer service, billing, and voicemail services all require a certain acceptable response level set by the decision-maker. To remain able to provide quality service to the customer the system must be looked at for possible software and hardware updates. The decision-maker has to take into account how much control is adequate over the MAC's and billing based on his/her source choice. It is important that the personnel conducting the MAC's, software upgrades, and call volume analysis have the needed skills to perform these duties at an effective and efficient level.

For Maintenance, Figure 4-3, there are few tasks because of the high system reliability. Card replacement within the switch along with the computerized system configuration must be done in a timely fashion so that the system or portion thereof does not remain down for an extended period of time. In order to keep the system able to accommodate the rapid and changing needs of the telephone customer there be a constant awareness of software upgrades available to increase the abilities of the switch. In order to conduct these upgrades of software and timely card replacement, the maintenance personnel must have the needed expertise or must have just had training on the new technology to keep the system current.

3. Level Three

In Figures 4-1 to 4-3, the alternatives for sourcing the different functions of the PBX switch, in-house, mix of in-house and contract, and contract out, are found as level three of the hierarchy. Using the functional criteria the decision-maker must evaluate the viability of each source option based on the threshold settings for each criterion. After making the needed threshold judgements he/she is able to then make the source decision for the respective foci. The ultimate source choice is then made by looking at the choices for each of the foci. Ideally, this would result in a clear-cut decision, however, most likely the decision-maker would need to make some additional trade-offs among the hierarchies. This is true especially in the case of an organization the size of NPS because the personnel performing the function may also be the same personnel that can perform duties under another function. Ultimately the decisions are highly correlated to each other and difficult to separate into unique decisions.

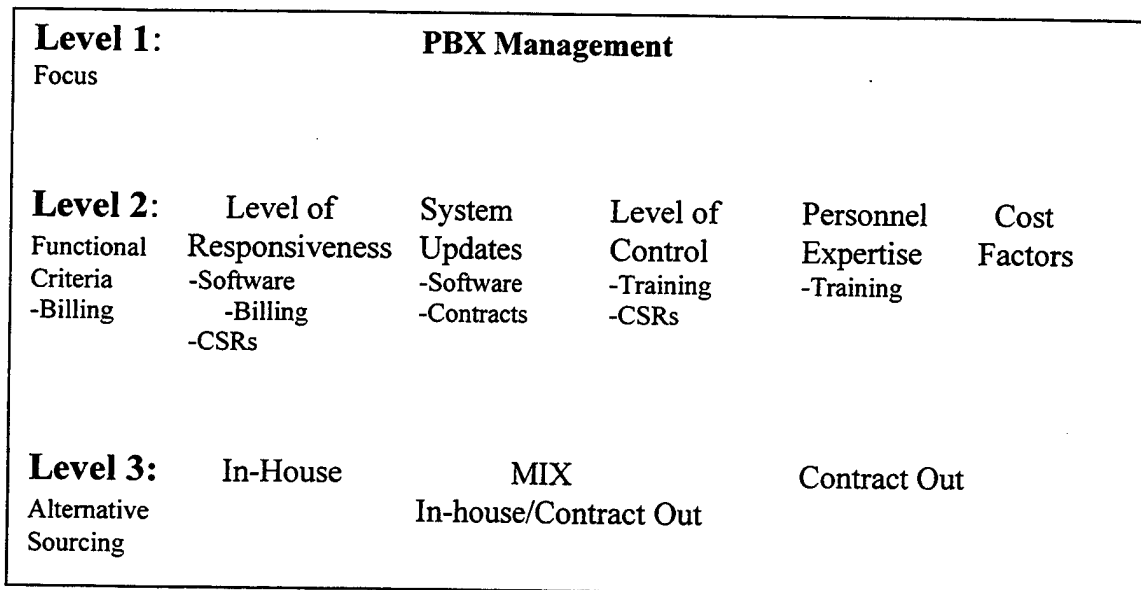


Figure 4-1. Hierarchy for Choosing PBX Management Sourcing.

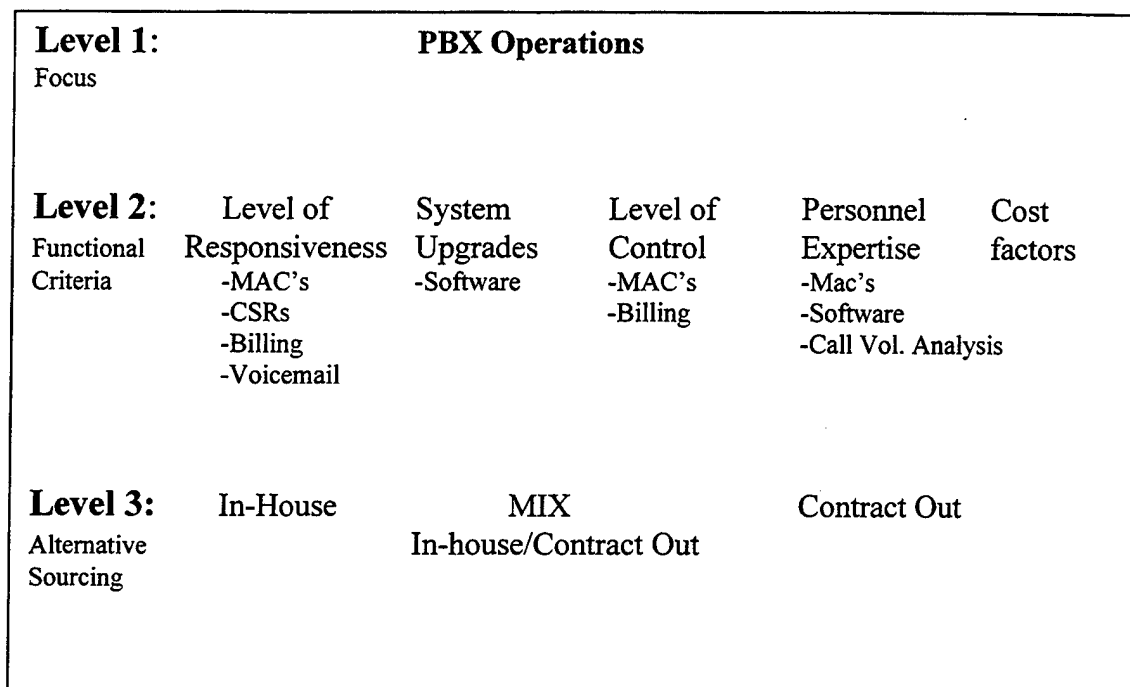


Figure 4-2. Hierarchy for Choosing PBX Operations Sourcing.

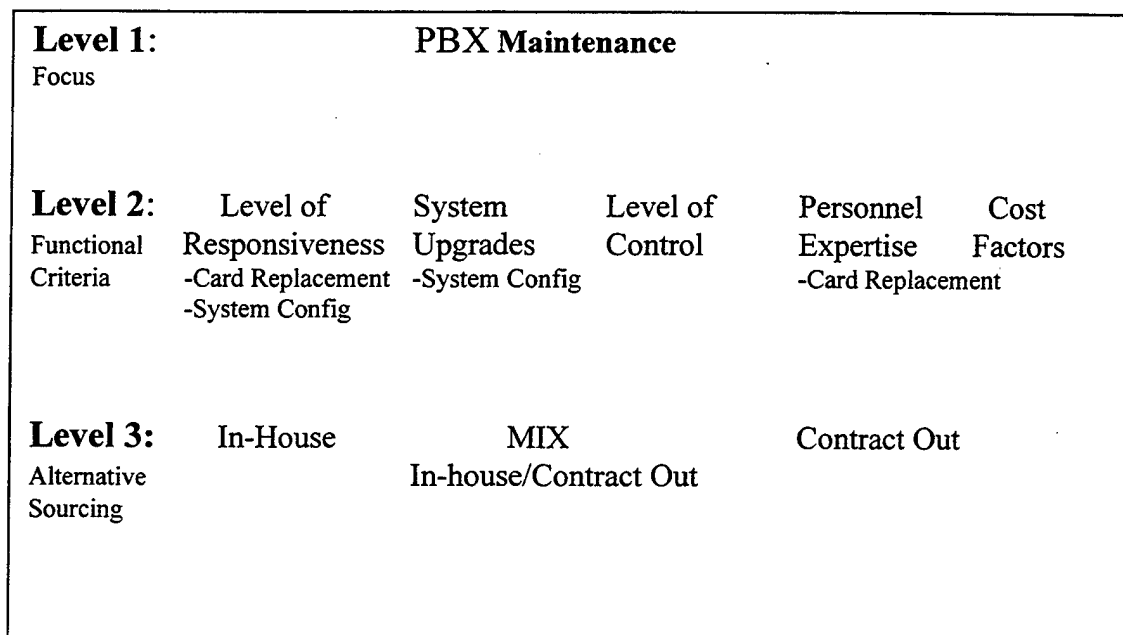


Figure 4-3. Hierarchy for Choosing PBX Maintenance Sourcing.

D. ANALYZING THE NPS AHP MODEL

These hierarchies' lay out the different considerations and relationships that must be evaluated when making the PBX management, operations, and source decision for NPS, or for any organization. From the hierarchies structures in Figures 4-1 to 4-2, one gains a clear sense that there are questions that the decision-maker must ask him or herself in order to come to an acceptable sourcing choice. The considerations that the NPS decision maker will ultimately look at are those same evaluations that each of the interview organizations had to consider. For the NPS decision-maker the added complexity of dealing with the government employee system also plays into the decision. For the decision-maker to come to a decision the questions that must be asked and answered are discussed below.

Upon installation of the new switch the DM must carefully check the services offered by the vendor and what is included in the purchase price of the switching system. It is important to know how much training will be provided at the time of purchase versus how much is needed to keep the switch operations up and running. This will allow for a basic formulation of an opinion based on cost as to which source alternative may be the most attractive.

The decision-maker must consider if there is enough resident expertise to conduct the management, operations, and maintenance functions. This is critical to NPS, because unlike civilian universities, who can hire personnel that have the necessary skills, NPS must consider the rules of government service that may not have telecommunications managers or technicians that have the requisite skills. Therefore, the technician must be sent to hours of costly training. From this perspective, because the government

employees are locked in on a government pay table day to day costs may be higher due to the fact in order to handle surges in demand for MAC's, voicemail request or other services there must be an employee slack. This paid down time at non-surge times may cost more than having a technician on-call for those expected or unexpected surge times.

Should the decision-maker find that there is not enough expertise within the organization and the expense is too significant to adequately train personnel, the option of using partial vendor contract or other partial outside contracts exists. Considerations of the personnel systems, employees' expectations in terms of job security and compensations must also be considered. The NPS decision-maker must keep in mind the limitations surrounding government employees and the necessary steps required for outsourcing that must take place if the latter option is desired. This option keeps the decision-maker from bearing as much up front cost for training while at the same time gaining the use of the new PBX. Once the personnel of the organization become familiar with the system, the option remains for the decision-maker to send the employees to training to become qualified to conduct more functions in-house thus giving more control over the system to the organization provided the contract is properly structured. To be able to effectively make this transition occur, the decision-maker must not lock into a long-term contract and must carefully track employee and contract costs and be prepared to reevaluate the initial sourcing decision based on new information. The potential savings to the organization can be substantial, because vendor supported services, albeit excellent and responsive are costly. By sending the organization's personnel to be not only trained, but cross trained, the organization is no longer paying twice; once for the employee and then again for a contract employee or vendor employee.

Another key issue is the need for the organization to continue to offer a PBX service that meets the needs of its customers. As new and innovative products are developed that can enhance the current PBX system, there must be employees who are educated in the new technology and are looking to keep the organization's system as current as feasibly possible. The decision-maker must evaluate his or her personnel base and make a determination if they have the skills needed to keep up with the ever-changing telecommunications environment. From the interviewed organizations, there was an indication that the personnel that are employed by the organization take more of a vested interest in the continued success and development of the switching services than contractor personnel. This must be factored into the decision-maker's decision on how to source key management, operations, and maintenance positions.

The philosophy of the decision-maker's organization plays an important role in the sourcing decision. If the organization determines the PBX system to be a core business unit within the organization then the desired level of control and sensitivity to cost is altered. Based on the data gathered, for those who treat the different switching functions as a core business unit, the organization, by default, wants a higher level of control and is forced to choose either the in-house/contract mix or a pure in-house source choice. This choice is based on the fact that when an organization considers their telecommunications as a core, they by default want higher levels of control over the different functional criteria. This high level of control is greatest with the in-house option and lessens as the source choice moves toward full contract support.

This chapter walked through structuring the PBX sourcing decision within the AHP hierarchy. By laying out the different sourcing choices, considerations, and

relationships, the author was able to clearly represent the variety of options and decisions that the decision-maker faces and must resolve before a sourcing decision is made. In Chapter V, the author will present his conclusion and recommendations based on the information presented in Chapter IV.

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V. CONCLUSIONS AND RECOMMENDATIONS

A. SUMMARY

This thesis aids the NPS decision-maker, facing a Private Branch Exchange management, operations, and maintenance sourcing choice, in making an educated and well-based determination. It first breaks down the telecommunication structure into its component parts, then illustrates a framework through which the decision can be organized and evaluated and finally incorporates the NPS decision into that framework for evaluation. By incorporating the experience of organizations that faced a similar sourcing decision, the author was able to lay out the necessary considerations in the framework and provide the decision-maker with a logical method of thinking about the choice he or she faces.

B. CONCLUSIONS

This thesis attempted to answer the question of what are the critical considerations for making a good sourcing decision for the NPS PBX and whether the AHP was a good framework for telecommunication decisions. Several conclusions can be drawn from the information gathered and from the processing of the data.

1. Critical Considerations for Sourcing the NPS PBX

When making a good management, operations, and maintenance sourcing decision, the critical considerations were summed up and explained in Chapter IV. First and foremost, the decision-maker must understand the decision criteria and the

relationship among the criteria and its environment. The AHP constructed in Chapter IV provides the framework. The decision-maker also needs to consider the current state of the organization and what it would take to get to the chosen sourcing option. A recap of these considerations should help to secure their importance and necessity to the decision-maker. Recall that the decision-maker needs to evaluate his or her work force and determine whether they have the expertise necessary to conduct switch functions after installation or if they require significant switch specific training. Should the latter in-house options not satisfy the decision-maker from a cost trade-off perspective then he or she can opt to contract out to the vendor or through another outside contract. The option also exists to use a combination of both in-house employees and contracts to satisfy the organization's needs. As discussed in Chapter IV, the contract options present unique concerns of their own. The decision-maker when faced with government service employees must be conscious of outsourcing procedures and policies and from a commitment perspective, must be aware that contract employees may not have the same commitment to the organization as those that belong to the organization's staff.

Also recall that based on the organization's desire for a certain level of control as compared to costs, a decision may be forced down a sliding scale from the highest control associated with the in-house setup to the lowest control associated with the full contract set-up. The AHP and the hierarchies for this particular decision provides a framework for the decision-maker to consider these options. These hierarchies allow the decision-maker to cross connect and compare the different levels of the hierarchies and based on the priorities particular to the organization, execute a proper sourcing choice.

2. The AHP for Telecommunications Sourcing Decisions

As described in Chapter III the AHP is a dynamic framework that allows the mind to process a complex decision in an organized and complete manner. This framework is a good fit for a telecommunications management sourcing decision, because not only does it structure the problem and decision criteria, it allows for related functions to be evaluated on an equal basis. From this framework, a decision or understanding of the problem becomes considerably more clear. This makes a sourcing decision seem less complex. Applying the lessons learned from other organizations facing the same type of decision into the framework makes it a powerful and rich tool on which to base a sourcing decision.

C. RECOMMENDATIONS

From the AHP hierarchy structure and considerations laid out in Chapter IV, along with the inputs from the various interviewed organizations, the author makes a recommended course of action for the NPS decision-maker. From the author's limited knowledge of the decision-maker's priorities, he suggest that NPS follow the same path as university D. NPS should staff the management and operations functions of the switch with government service employees and leave the maintenance to be conducted by the switch vendor. This will allow the unique needs of the organization to be addressed by the in-house staff and expert maintenance to be gained through switch vendor personnel. Such a set-up provides an optimal level of control, high reliability, and relatively lower initial personnel start-up cost. It also provides the greatest amount of flexibility for NPS.

Furthermore, NPS must carefully track the costs of the contract and that of the employees so that a reevaluation of the current sourcing structure can be done. NPS must also document the reasons and logic behind whatever decisions are made. This will prevent a disconnect when it comes time to make a major change or update to the PBX in the future, because the decision-maker can then look back and have a firm understanding of how to base his or her next decision. Also if a sourcing choice winds up being less than desirable, the organization will know from what point to reevaluate in order to change the sourcing structure. The tracking of the decisions and costs by the organization is vital and could be the difference between making an average sourcing choice to making a good quality sourcing choice for the organization. By following these recommendations, NPS should be able to keep a PBX system that is reliable, up to date, and meets customer needs for years to come.

D. AREAS FOR FURTHER RESEARCH

Further research in this area can be accomplished by applying the full Analytical Hierarchy Process framework all the way through priority setting and using Expert Choice software. The main challenge would be in getting cost data for NPS as well as for other comparison organizations because it is both scarce and difficult to obtain. Ultimately, further research would involve having an intimate knowledge of the NPS decision-maker's set of priorities and cost tradeoffs and then structuring them using the AHP.

APPENDIX A. ORGANIZATIONAL QUESTION SHEET

Phone System Questions

Do you operate your own switch?

If so, for how long?

If not, what do you do?

What types of services does your system offer?

PBX-Voice over IP

CTI; SMDR; Provisioning Analysis

Voice Mail; Detailed billing.

What size, how many phones, lines?

Who does the maintenance/operations of your system?

If Contracted then

What was the reasoning for your choice?

Did you do it differently before?

What was the reason for the change?

What types of drawbacks or advantages have you witnessed in reference to your choice?

What tasks does the staff do and how many per task?

-# of personnel

-Maintenance

-Operations

What size budget do you have?

How many adds /moves/ changes do you conduct each year.

What are your yearly costs?

Give a break down by task if possible?

Statistics-Brief Description

-Size, #lines, etc...

Why the contractor and what type of contractor –free lance firm or corporate support from a switch supplier (ie. Lucent)?

What type of service agreement do you have?

How satisfied are you?

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APPENDIX B. RESPONSES FROM ORGANIZATIONS

	University A	University B
Switch Operation	Several of our switches we operate ourselves and have for more than 5 years. These are our Lucent G3I and R systems. If not, what do you do? We also have Pacific Bell Centrex and GTE Centranet. The GTE service used to be our own 5ESS switch that we operated ourselves for 5+ years.	Technically, we do operate our own switch in that we have a telecom dept that does its own MACs and installs. In addition to our own staff, we have two full time technicians that we contract from our vendor, Ericsson, but who work under our direction. We have operated in this mode since 1984.
Services	PBX-Voice over IP Not at this time, but we are exploring. CTI; SMDR; Provisioning Analysis We are in the process of installing a CTI application, we have SMDR, I am not certain what you mean by provisioning analysis. Voice Mail; Detailed billing. We provide Voice Mail and detailed billing	We operate like a telephone company on the campus. We provide a full range of telephone service, Voicemail, 800 Mhz radio, directory, billing, installation and repair. We operate as an auxiliary business enterprise. We receive no state funds, all of our revenues come from our customers.
Size	5ESS Centranet - about 10,000 lines G3R - about 7,000 lines G3I - about 400 lines PacBell Centerx - about 600 lines	9000 telco customers 5500 lines 150 buildings 3 Off campus remote locations 3000 Voicemail Customers 300 Radio Customers
Maint/Ops set-up	Depends on the system Did you do it differently before? Yes What was the reason for the change? The 5ESS costs too much to maintain and keep current from a software perspective.	

Changes			
Adv/Disadv	Our vendor, GTE, does not have technicians on site that are as skilled in all aspects of our systems. Nor are their people committed to the University the way our own people were. Expedites are more difficult. We expend resource managing the vendor, rather than the system. We no longer have the amount of debt service that we did, nor do we face huge expenditures on a yearly basis for keeping the system current.		
# of Personnel	Maintenance - Technically none, except for monitoring some aspects of the systems. However, we do get involved to coordinate system and facilities maintenance. Operations -None, we do have a staff of 8 performing customer interface, trouble call receipt and tracking and a staff of 3 handling technical support, vendor management and planning. These people work with all of the products and services that we provide, not just the PBX. Additionally, we have contracted with an outside vendor for station and cable installation and repair.	We have 12 FTE dedicated to telephone operations: 5 CSRs in customer service, 2 programmer analysts who maintain the billing, WEB, cable facility and directory Oracle databases, 1 telco analyst that analyses our network providers bills, (PacBell, MCI) maintains our customer rates database, produces the our billing for our student and administrative billing cycles, 1 voice services analyst that manages the PBX, voicemail and other voice systems, 2 contract PBX technicians and 1 telecom manager. In addition, there is a staff of 5 network technicians that can be called upon to perform MAC as workload dictates.	
MAC's/yr	Don't Know	Est 12,000MACs per year We install 4500 students every fall and terminate 4500 every June	
COSTS	Proprietary	What are your yearly costs? \$4.2 Million (we are a non profit) Wages, salaries \$.7million Local & LD usage \$1 million Equipment & \$.2.5million	

Why contract	<p>Why the contractor and what type of contractor –free lance firm or corporate support from a switch supplier (i.e.. Lucent)? GTE (in this case a free lance firm because we are not in GTE territory), they offered a total package of services and dollars that was attractive. GTE was looking for a point of presence in the area to begin offering its services outside of their traditional territory. We wanted someone with the resources to manage the switch and provide us back a reasonable service commitment.</p>	<p>As part of our maintenance agreement with Ericsson we decided to subscribe to their dedicated technician service, primarily as we required a fully trained PBX technician as opposed to a MAC technician. The Ericsson technicians work under our direction as well as performing Ericsson specified switch maintenance work.</p>
What type	<p>What type of service agreement do you have? 5ESS - 7 years with an option for a three year renewal. Station maintenance and repair is bi-annual.</p>	<p>We have a 5 year service agreement that covers equipment replacement and 2 dedicated technicians, one PBX tech and one MAC tech.</p>
Satisfaction	<p>How satisfied are you? Marginally to reasonably when considered from a cost perspective</p>	<p>Our satisfaction varies, Ericsson as a company has been cutting back on their service commitments in the face of stiffer competition and lower margins. On the other hand we have not invested in fully training our staff to be totally independent of our vendor. We are capable of doing self installs on small projects and can use our dedicated Ericsson tech to do these tasks at no extra cost to us. This provides us significant installation savings. On the whole it seems to be a pretty good arrangement. Level of expertise with Ericsson techs is uneven and sometimes frustrating.</p>

	University C.	University D.
Switch Operation	Yes, 14 years Nortel SL-100;	Yes, 8 Month Lucent Definity G3R, 15 years Mitel SX2000
Services	<p>All of these plus IVR, CATV, facilities engineering, network provisioning, LAN & backbone support, wireless services, operator services 7x24, paging services, card readers, etc.</p> <p>PBX-Voice over IP</p> <p>CTI; SMDR; Provisioning Analysis</p> <p>Voice Mail; Detailed billing.</p>	<p>PBX, CTI, ACD, CDR, Voice Mail, IVR, ISDN, PRI Trunking, Multimedia messaging, Call Center statistics and reporting, Voice over IP, Switch Management, Performance and resource analysis</p>
Size	35,000 phone lines, 50,000 networking addresses, 130 million phone calls, 20,000 voicemail boxes, 10,000 pagers, 7,000 CATV drops	Sized to support 10,000 stations. Currently about 6,000 stations in operation. We have approximately 375 trunks attached to the switch.
Maint/Ops set-up	<p>In House-----Back-up emergency service with Nortel in addition</p> <p>What was the reasoning for your choice? Improved service, lower cost</p>	<p>We perform operations of the switch with internal staff.</p> <p>Basic maintenance is provide with internal staff.</p> <p>Advanced maintenance and repairs are contracted with Switch vendor</p>

Changes	Self Maintained from beginning	Yes. On the old Mitel switch we performed self-maintenance in the later years. Original years, it was on full maintenance, but as we became more experienced and the costs of self-maintenance became better than contract we brought it in-house.
Adv/Disadv	Incredible advantages in service levels, preventative maintenance, future capacity and technology planning, lower cost per line and per year We do not see any real disadvantages	No drawbacks. Advantages would be fast response, quality response, remote monitoring of alarms which results in Lucent knowing about problems before we or our customers do.
# of Personnel	On many systems actually: voicemail, CATV, Networking, modems, paging system, etc. Currently at 5 technicians who take trouble calls, clear problems, etc. In addition there are 5 field technicians doing wiring, field troubles, moves, adds, changes, etc. Field techs do both maintenance and operations -Operations On same systems 4 system engineers for planning, commissioning, routing, advanced troubleshooting, etc.	I have 2 FTE staff assigned to Telecommunication needs. Additionally, there are about 40 hours per week of part-time assistants. These 2 staff and part-time staff perform all maintenance and operations. Since we have a contract that does most of the maintenance, the staff primarily do Operations related tasks (adds/moves/changes).
MAC's/yr	Approx 14,000 yr Approx 3,500 trouble calls, Approx 40,000 help desk calls	1500
COSTS		Unable to specify Too new

Why contract		<p>On the new Lucent Switch, we do not have any experience in maintaining it, so we went with a full-contract to support it. In future years we will evaluate the costs and benefits of moving to in-house maintenance</p>
What type		<p>We contract from the vendor, Lucent, to maintain switch. We are still in the first year of installation and the maintenance is part of the purchase price for year 1. We are continuing beyond year 1 with Lucent to take advantage of several contract benefits which an 3rd party provider cannot provide. Additionally, Lucent provides 24 hour monitoring and expert systems which others vendors do not.</p>
Satisfaction		<p>Very Satisfied: Lucent stays on top of the whole system, they realize problems before we can call them. There is a high price tag for this level of satisfaction. The phone system is considered a core business unit for the school. The plan is to move toward bringing the the current lucent maintenance contract in house as we get more training on the switch.</p>

	University E.	University F
	5ESS Switch since 1994	Lucent Switch since 1997
Switch Operation		
Services	Voice mail, call tracking and analysis, The switch is supported by a Unix-based TMS. No CTI.	Basic services, voice-mail, ISDN capable. Analog and ISDN service. ISDN sets are basic 10 and 20 button ISDN types. VTC capable
Size	5800 dial-tones, 2800 active mailboxes, 30% ISDN, %70 analog.	There are about 1491 stations. 3 ISDN trunks. One for outgoing, 48 trunks using T1. One is for DID, 44 trunks using T1. One is for SDN/DOD using 93 trunks.
Maint/Ops set-up	Contract through Telco for 2 1/2 years, Telco monitors switch.	Contracted

Changes		Switching was done through Telephone Company Centrex.
Adv/Disadv		No Drawbacks or disadvantages thus have been noticed thus far.
# of Personnel	2 GS; 1 does Octell voicemail service, 1 does MAC's; Telco has 2 Techs that do cabling on call and MAC's.	We have a staff of 7. Two of us handle the telecommunications part, two handle the data side, one does the video with support from the telecommunications techs, one handles the accounting part, and one is responsible for taking service orders and repairs and in charge of the receptionist position.
MAC's/yr		
COSTS	proprietary	

Why contract	Contract was set up due to lack of expertise in the department and the failure of GS management of system.	The reason we elected to have Lucent Technologies handle our maintenance is because of their 24/7 motorizing of our switch. We also like the response when we need equipment and assistance over the phone when necessary. There is also a lot of support of the users network that has been set up.
What type		
Satisfaction	Not very satisfied. Should have about 11 people working on the system. The telco is less than timely in response to our needs. The GS employees are not skilled enough to do all the functions that is required to keep the switch up and running. The best method to increase satisfaction is 1. contract for expertise and 2. get software upgrade for TMS.	

	Corporation One	Government Agency
Switch Operation	Yes, since the install about five years ago. Nortel Meridian 1 Option 81C	Lucent Definity Digital Switch since January 1999 updated from an older Lucent switch.
Services	<p>PBX-Voice over IP Our PBX is a Nortel Meridian 1 option 81C. No voice over IP, too early and experimental to run our entire PBX on.</p> <p>CTI; SMDR; Provisioning Analysis</p> <p>Voice Mail; Detailed billing. Our voicemail is on a separate Octel 250/350 and handles voicemail for all of our U.S. sites. For billing, we have a CDR port on the PBX which goes to a call buffer and the raw data is downloaded by a outside company which formulates it into billing info.</p>	Voice over IP, SMDR; Provisioning Analysis. We also provide Voice Mail and detailed billing
Size	In San Jose, we are currently operating at about 3500 total active, physical lines with another roughly 400 phantom and ACD DID numbers through the PBX and about 9 circuits coming in from our CO.	Using 4600 stations expandable to 6000 stations
Maint/Ops set-up	We have an outside service contract. With the exception of we do our own MAC's.	24/7 Lucent Maintenance contract, We perform our own MAC's

Changes			
Adv/Disadv			
# of Personnel			There are 5 people in the telecommunications department that handle the management and operations. Billing is done through an outside government agency that downloads the billing data and then sends it back to us.
MAC's/yr			300-500 per year
COSTS			not available

Why contract	With a switch of this size and two other corporate sites in California privately networked off of it, including voicemail, you have to have a provider for priority alarms and such cause it is your neck when something goes wrong and the budget allows for it.	not available
What type		not available
Satisfaction	They are a corporate service (GTE) They cover troubles and equipment, this varies for the other U.S. sites but they cover all of our U.S. sites. If we want them to do MAC's for us or any day to day stuff we have to pay them extra per hour. I've only been here, in this position for about one month and they have been good so far.	Very satisfied. Lucent service is very good and knows of problems sometimes before we do.

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